



**Treatment of Richard Mine Acid Mine Drainage
Contract # RM-MON-1
Phase I
Evaluation of AMD Problem Report**

for the
West Virginia Conservation Agency
Monongahela Conservation District
and
Natural Resources Conservation Service
Monongalia County, West Virginia

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Introduction

The Richard Mine Acid Mine Drainage (AMD), which originates from the underground abandoned coal mine identified as the project site (Site), is located near Morgantown, West Virginia in the Deckers Creek Watershed (Figure 1). Deckers Creek is a tributary of the Monongahela River. The Monongahela River flows north and joins the Allegheny River to form the Ohio River in Pittsburgh, Pennsylvania. The Deckers Creek watershed lies between the Monongahela River and the Cheat River.

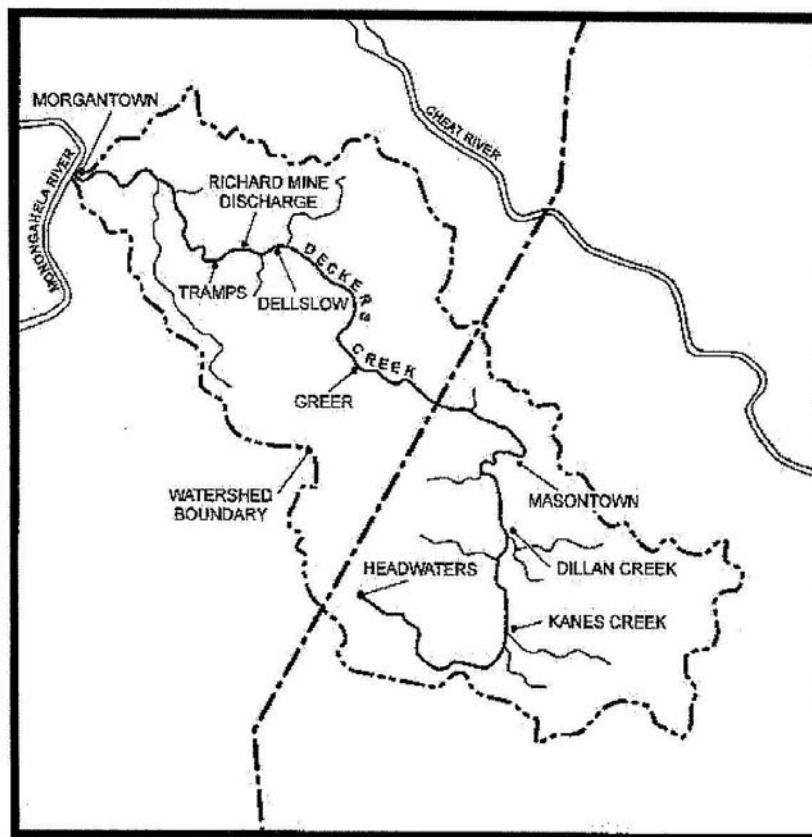


Figure 1

The Site is located in the community of Richard, near the Intersection of Interstate 68 and State Route 7, southeast of Morgantown, West Virginia in Monongalia County. The underground mine works are located between Deckers Creek on the South, Interstate 68 to the West, Cheat Lake to the North, and Tibbs Run and Maple Run on the East. The mine works underlie the residential areas of Brookhaven, Meadowlands and Imperial Woods. The Site is located on the Morgantown South USGS 7.5 minute quadrangle (Figure 2).

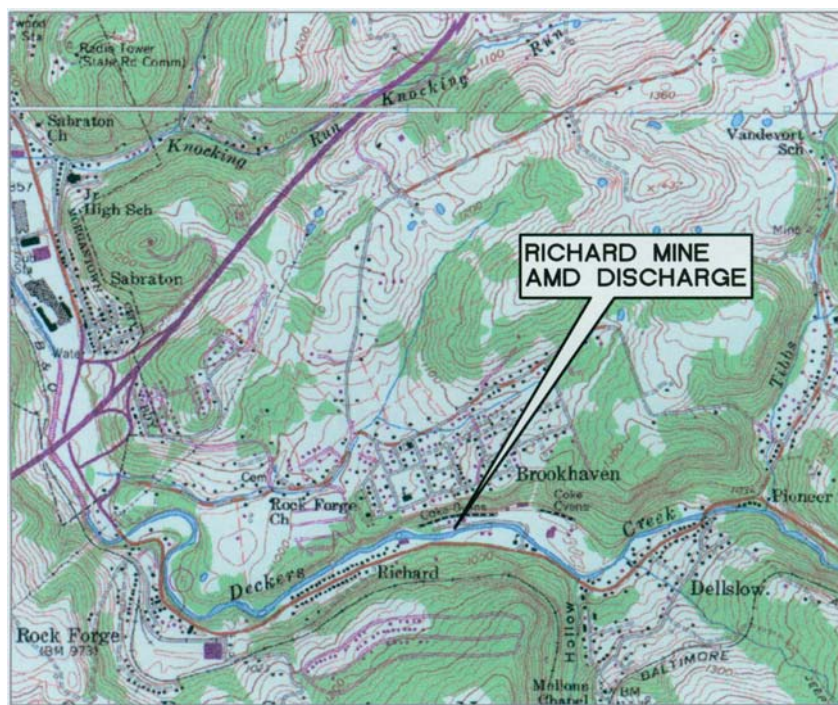


Figure 2

The Richard Mine delivers the single greatest AMD contribution to Deckers Creek in its entire length. It loads Deckers Creek with Aluminum, Iron and Manganese at rates of 59,000, 143,000 and 3,200 lbs/yr, respectively (Stewart and Skousen, 2002). Pollutants from the mine can be tracked downstream in Deckers Creek, and account for most of the load (the measure of flow and parameter concentrations) it carries through the City of Morgantown.



Figure 3

The Richard Mine drain releases a relatively small amount of water compared to Deckers Creek. Measurements of the flow from the Richard Mine range from 0.22 to 1.27 cfs, whereas estimates for the flow of Deckers Creek under the bridge at Dellslow, just upstream of the Richard Mine discharge, range from 1.9 to 119 cfs. The Richard Mine discharge approximately doubles the load of sulfate in Deckers Creek. The Richard Mine discharge adds virtually all the iron and aluminum that are found in the creek for the rest of its course. Water from the Richard Mine also contains high concentrations of manganese (~5 mg/L), but does not bring manganese up to detectable concentrations in Deckers Creek.

The aluminum and the ferric iron contributed by the Richard Mine discharge are rapidly converted to hydroxides. Deposits of these hydroxides coat the rocks at the mine discharge. The ferrous iron, on the other hand, remains in solution, and gradually turns to ferric iron, and then to a hydroxide as the creek flows through the town of Sabraton.

The acidity in the water from the Richard Mine discharge does not cause Deckers Creek to become acidic. Rather, it seems to affect the creek by adding metals, some dissolved, some as suspended particles. These hydroxides give Deckers Creek its somewhat milky appearance (Figure 4).



Figure 4

Analyses of the forms of the metals can be used to understand the alkalinity levels in the water. Deckers Creek has approximately 0.7 tons/day of alkalinity before it encounters the approximately 1.2 tons/day of acidity coming in from the Richard Mine discharge. The aluminum and ferric iron use up the alkalinity as they become hydroxides, but the ferrous iron remains in solution, and comprises

almost all of the acidity remaining in Deckers Creek as it passes through the town of Sabraton.

The primary focus of the Project is the treatment of the existing AMD discharge from the mine seal that was installed by the West Virginia Department of Environmental Protection (WVDEP). The discharge flows across private property from an 18-inch diameter pipe (Figure 3) into a 44-inch wide concrete trench (Figure 5), then into a concrete lined trapezoidal channel (Figure 6), and finally into Deckers Creek.



Figure 5



Figure 6

The goal of the Project is to implement a solution that will result in improved water quality in Deckers Creek suitable for sustaining warm water fish and other aquatic life. By analyzing the AMD associated with the Richard Mine discharge, it is then possible to develop a comprehensive list of alternatives to potentially mitigate the AMD problem. The goal will be achieved through the review of existing water quality and quantity data, geologic data, other readily available data, and mapping. The purpose of the Project is to identify treatment alternatives for the AMD problem at the Richard Mine discharge, and to design a construction project to potentially reduce / eliminate the contaminated water from entering Deckers Creek or to improve the water quality of the AMD so that it does not degrade the water quality in Deckers Creek.

Site Description

Topographic Setting

The Site is located on a relatively flat area between Deckers Creek and a steep slope. The flat area was developed as part of the mine development. The Site currently has several storage buildings and a residence. (Figure 7). An aerial photo view of the Site is shown on GAI Drawing E-B3. Drainage channels cross the Site to convey surface and mine drainage to Deckers Creek.



Figure 7

The development for the mining at the Site created a highwall located at the base of the steep slope. The highwall has since been reclaimed by a grass covered soil slope. Several coke ovens were located within the highwall at the approximate level of the Upper Freeport Coal.

Geologic Setting

The surface geology of the Deckers Creek watershed is part of the Pennsylvanian Period, namely the Monongahela, Conemaugh, and Pottsville Groups and the Allegheny Formation¹⁵. The dominant rock types include sandstone, siltstone, shale, limestone, and coal. The mined coal interval at the town of Richard is the Upper Freeport Coal. A generalized section is presented in Figure 8.

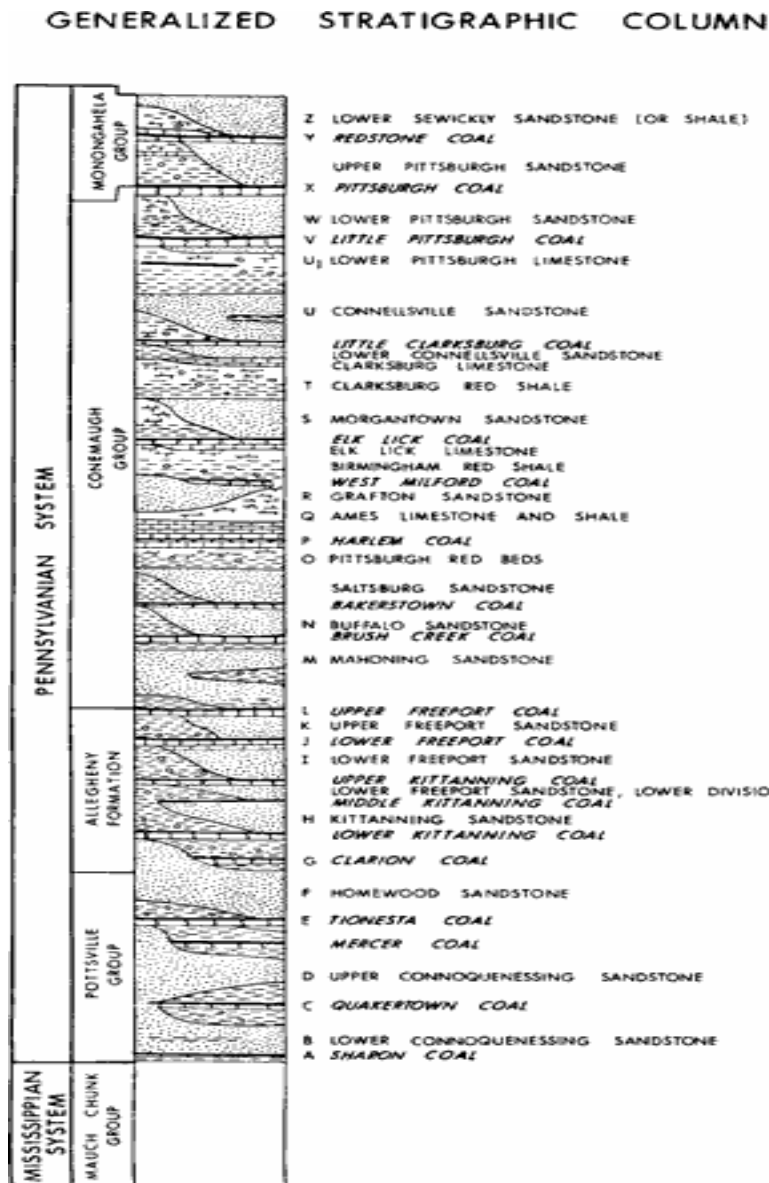


Figure 8

Major soils in the area include the Gilpin (fine-loamy, mixed, active, mesic Typic Hapludult) and Dekalb (loamy-skeletal, siliceous, active, mesic Typic Dystrudept) series on the uplands and the Atkins (fine-loamy, mixed, active, acid, mesic Fluvaquentic Endoaquept) and Pope (coarse-loamy, mixed, active, mesic Fluventic Dystrudept) series in the bottomlands¹⁵.

The bedrock layers of the Deckers Creek watershed generally slope down from the southeast to the northwest, but there is one large fold, or anticline, in the rocks. In the center of this fold, older bedrock is pushed up through younger bedrock. The oldest bedrock appears where Deckers Creek has cut a gorge through this fold. Younger bedrock lies on the ridge formed by the fold, and even

younger bedrock appears at either end of the gorge. These rocks are important. In the Deckers Creek watershed, the coal seams are in the younger bedrock. The Upper Freeport Coal covers the entire watershed except where the anticline has pushed up into it, and where a few of the major tributaries have eroded it away. The Pittsburgh Coal seam occurs only near Morgantown. The oldest rock with substantial exposure is the Greenbrier Limestone, which is found and mined where the creek cuts through the center of the anticline at the town of Greer.

The Site is located 1-1/2 miles southeast of the Connelsville Uniontown Syncline. The rock across the Site dips to the northwest at approximately 375 feet per mile. The Upper Freeport coal in the Richard Mine is only four feet high and lies at a relatively steep slope of approximately 8 percent.

Figure 9 shows the extent of the Upper Freeport coal in the area. According to the West Virginia Geological Survey, Marion, Monongalia, and Taylor Counties¹⁶ the Upper Freeport Coal was mined in the area of the Site by Elkins Coal & Coke Co. No. 1 Richard Mine.

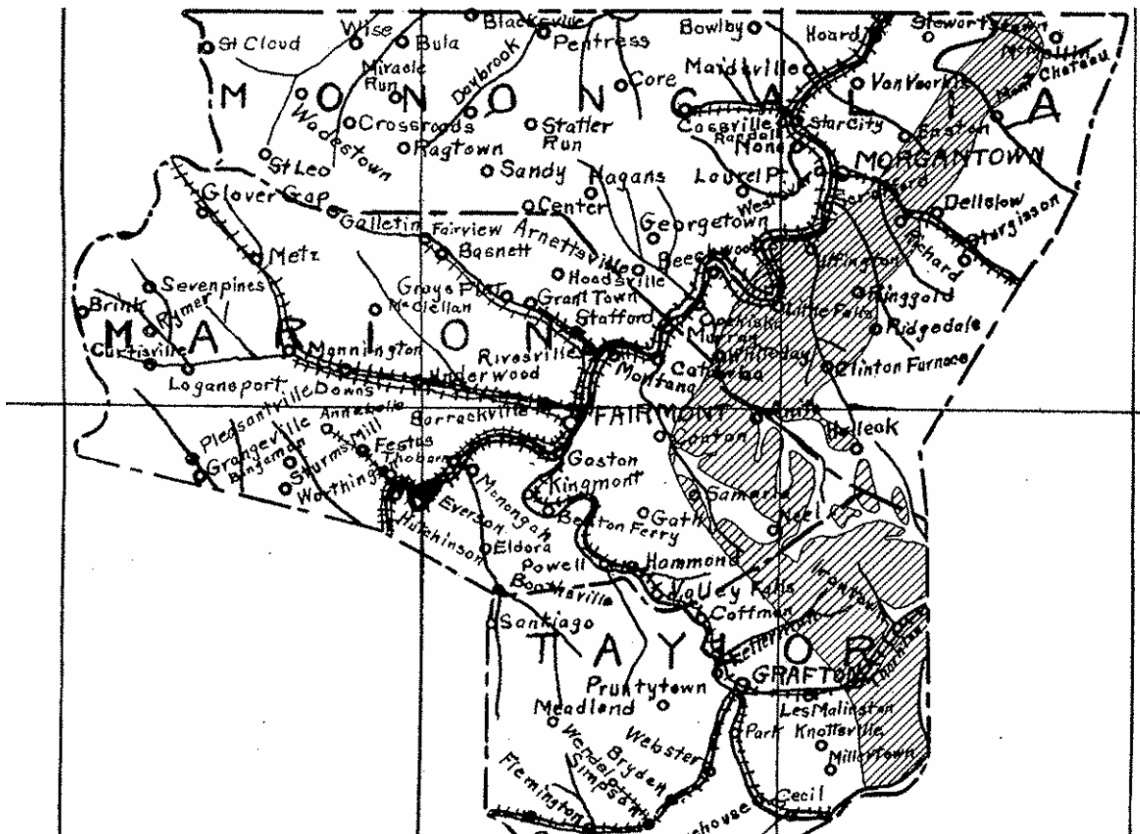


Figure 9

The Upper Freeport Coal seam is the topmost strata of the Allegheny Formation of the Pennsylvania System. The Upper Freeport coal is relatively low in sulfur (<1.5%) and has a moderately low ash content (8 to 12%). It is a multiple-bedded seam that is divided into a top coal and bottom coal, separated by a shale interlayer, all averaging a total of six feet in thickness (Hennen and Reger, 1914). The overlying strata in the Conemaugh Group contains several massive sandstones and some shales. Limestone or alkaline-bearing rock units are not generally found within 50 meters above the Upper Freeport Coal in this area, so very little overlying geologic material is available for acid neutralization¹⁶.

Mining Discussion

The Richard Mine opened in 1936 and was known as “Industrial Collieries Corporation #21.” Before the mine was closed in 1952, it had become known as the “Bethlehem Collieries Corporation #21”. The mine produced more than six million tons of coal and at its peak in 1942 it produced approximately 670,000 tons of coal and employed roughly 540 workers. The industry became the basis of a small community, and many landmarks from those days can still be seen. While the Richard Mine was operating, coal mining was changing from hand loading, which was accomplished with picks, shovels, and muscle, to mechanical loading, which used a forerunner of today’s continuous mining machines.

Local residents who worked within the confines of the Richard Mine have explained that the water in the mine most likely came from the entire roof of the mine. It is believed, by these local residents, that there was not any particular spot where most of the water originated. Numerous stories have been documented of a large amount of water within the mine during the operation days causing wet working conditions and a necessity to find drainage outflows.

The landowner of the Site has indicated the mine had a blowout in the 1980’s causing flooding of his property. A portion of the Richard Mine has been previously reclaimed through efforts of the WVDEP as discussed in detail below. The landowner of the Site also described the layout of the mine, as he knew it, which included the fact that the main entry into the mine was approximately 500 feet to the east of the mine seal and the low point of the mine was to the west of the mine seal.

Site Reconnaissance

A site reconnaissance was performed on May 11, 2006. An aerial photo with significant features identified is presented on GAI Drawing E-B3. The discharge pipes from the mine were visually observed and had recently been cleaned by the WVDEP. Flow from the mine piping system into the concrete trench was observed. In addition, a minor amount of flow was observed coming from the mine opening at the end of the concrete trench under a concrete slab crossing to one of the storage buildings. The reclaimed slope along the highwall and coke

ovens was observed. Within the slope is a set of mine drain pipes with no flow. A secondary channel is located along the base of the reclaim slope and drains to the north and crosses the Site to Deckers Creek.

Moderate red staining was observed along the concrete trench and concrete channel. From the confluence of the concrete channel and Deckers Creek, moderate red staining was observed, as well as, white precipitate. Deckers Creek appeared to be a milky color.

A brief site visit of the discharge at Cheat Lake Middle School was performed. The discharge is located in close proximity to a baseball field. There was evidence of staining in the unnamed tributary downstream of the discharge.

A second field reconnaissance was performed during the bench scale testing on June 15, 2006. Additional visual observations were performed at the Site. The drainage from the mine seal is conveyed through three PE pipes. The primary discharge is through an 18-inch diameter PE pipe. A very small flow was also located to the west behind the last storage building. Emanating from the grass lined channel, was a flow less than 5 gpm which drained under a concrete slab west of the building, under the road, and through the secondary channel to Deckers Creek.

The discharges along Tyrone Rd (to Tibbs Run) were investigated. The pump facility off County Route 67/4 was located. Tibbs Run Reservoir or associated openings was not found and it was deduced that the impoundment had been removed during residential development of the area. It was also determined the discharge to the unnamed tributary of Tibbs Run off Meadowland Road was dry. Tibbs Run exhibited less than 20 gpm of unremarkable flow at Meadowland Drive.

The discharge at the Cheat Lake Middle School was observed in the unnamed tributary of White's Run toward the ball field. At the footbridge upstream of the library, the presence of many case building caddisflies were observed, but no other sensitive taxa. There was moderate iron staining in the creek at this location.

Within 100 feet of this location, walking upstream along the recent pipeline reclamation, a dramatic increase in iron staining in the creek was noted. No benthics were observed in this area. Walking further upstream, the source of the iron staining was identified as an opening that was consistent with the mine works of the Richard Mine. It was located within 50 feet of the limits of the baseball field. A small tributary just upstream of the discharge was unstained, exhibited healthy benthics, but was joined by another red tributary from the east. This indicates there is additional iron drainage further upstream of the ball field area.

Records Review

The following documents were provided by the Contracting Officer for review:

- Supplemental Watershed Plan No. 1 and Environmental Assessment for the Upper Deckers Creek Watershed, September 2000. The review of this document permitted an understanding of the issues within the Deckers Creek Watershed and the goals of those involved in the Plan.
- *Background Paper on the Richard Mine* prepared by the Friends of Deckers Creek (FODC). Upon review of this document, GAI was able to comprehend the purposes and focus of the Project.
- NRCS Map of Richard Mine Showing Mine Workings, Contours, and Mine Openings. This is an overlay map of the mine workings and the USGS topographic map of the area. This map includes information obtained from the 1944 and 1947 mine maps. The information from this map has been included on GAI Drawing E-B2.
- Selected drawings of the original Wet Mine Seal design prepared in 1990 by Sturm & Associates for the WVDEP. Using these drawings and the discussions with the WVDEP (below), GAI was able to understand the processes utilized to date and their failures and successes.

In addition to the material supplied, several other sources were obtained and reviewed. These include a review of the internet site for the FODC, USGS topographic maps (both current and historical), aerial photography (both current and historical), internet sites pertaining to the Richard Mine and numerous articles/papers on acid mine drainage.

The tax maps for the area have been obtained and are presented on GAI Drawing E-E2.

On June 5, 2006 GAI personnel visited the WVDEP offices in Philippi, West Virginia to review the files pertaining to the work completed at the Site and discuss these items with WVDEP personnel. The WVDEP (or its predecessors) has been conducting work at the Site since 1987.

On May 6, 1987 the United States Department of Interior's Office of Surface Mining (OSM) conducted a review of the Site for a potential blowout and possible flooding complaint made by the landowner and determined it did not warrant Federal Programs participation.

On April 14, 1988, the Richard Mine had a blowout discharge of approximately 5,000 to 10,000 gallons per minute at the Site. The Abandoned Mine Lands Division of the OSM had drainways and collector drains constructed to transport

the mine discharge to a more suitable area of the Site. These include the concrete trench and concrete channel discussed previously and other grass lined channels on Site (Figure 10). On August 15, 1989, the OSM followed up the work performed in 1988 by conducting a review of the Site and determined that no emergency conditions existed and that some maintenance would be necessary to provide proper drainage.



Figure 10

During December of 1990, the WVDEP had a mine seal constructed to control the discharge from Richard Mine. The wet seal was constructed to discharge to the existing concrete trench. By April of 1991 (less than four months later), the stone bulkhead for the mine seal had become clogged with iron deposits and the standard wet mine seal needed to be removed. The WVDEP had a concrete box installed to replace this wet mine seal (Figure 11).



Figure 11

In July of 2000, the WVDEP once again needed to modify the means of collecting the discharge from the Richard Mine. The concrete box installed in 1991 was proving to be inadequate due to the build up of iron precipitate. The WVDEP had a concrete wall constructed above the concrete box with two emergency overflow pipes to assist in the discharge (Figure 14). The mine continues to discharge at various locations at the Site including a mine opening under the concrete façade of one of the buildings at the Site. (Figures 12 and 13).



Figure 12



Figure 13

The WVDEP continues to conduct maintenance of the mine seal structure by flushing the discharge pipes on a semi-annual basis. According to the WVDEP personnel, these activities may be increased to quarterly in order to assure that blockage of the pipes is not occurring.



Figure 14

Hydraulics and Hydrology

A hydrology and hydraulics evaluation of the mine area was performed in order to characterize potential inflow and outflow points. The topographic maps available from the USGS quadrangles of the mine area were reviewed, and surface drainage structures were identified. The topographic mapping and surface features are shown on GAI Drawing E-E1.

The intent of this evaluation is to provide insight into the possible source(s) of water infiltrating the mine and locations of discharge other than at the site. Having an understanding of where the water within the mine originates and culminates allows for a better comprehension of the impacts of the water. This comprehension can provide the basis for a method to mitigate the AMD at the Site.

The Upper Freeport Coal seam outcrops along the eastern and southern portion of the mine workings and is significantly below drainage as the mine workings progress to the West. On the western edge of the mine workings, the coal seam is at approximate elevation of 700 to 750 feet which is approximately 300 to 400 feet below the ground surface.

The water elevation of Cheat Lake is approximately 870 feet and the Monongahela River is at approximate elevation 814 feet. These elevations are lower than the closest portion of the mine workings. Therefore, it is unlikely that they have any effect on the mine drainage.

Drainage from the mine workings would be anticipated to occur along the northern and eastern edge of the mine workings (i.e., near Cheat Lake Middle School) due to the dip, configuration and the location of a fault of the mine workings indicated by the mine maps. A portion (approximately one-half of the mine workings area) has a local dip to the South. Thus, a mine discharge occurs along the southern edge of the mine workings (i.e., at the Site).

The headwaters of six small streams and small water retention depressions were identified on the topographic mapping. Except for Whites Run, the streams should have a minimal effect on the drainage from the mine due to their limited drainage area and distance between the mine workings and the ground elevation. Whites Run and an unnamed tributary of Whites Run are located above the northern portion of the mine workings. Of the streams in the mine workings area, it has the largest drainage area and is the closest in elevation to the mine workings. However, no known connection between the stream and the mine workings has been identified.

Tibbs Run is located adjacent to the eastern edge of the mine workings. A small pond, Tibbs Run Reservoir, is located at approximately the crop elevation of the mine workings. In addition, a mine entry has been identified in the area of the

pond. There may be a connection between Tibbs Run or Tibbs Run Reservoir and the mine workings. The connection would be on the up dip side of the mine.

Water Quality Analysis

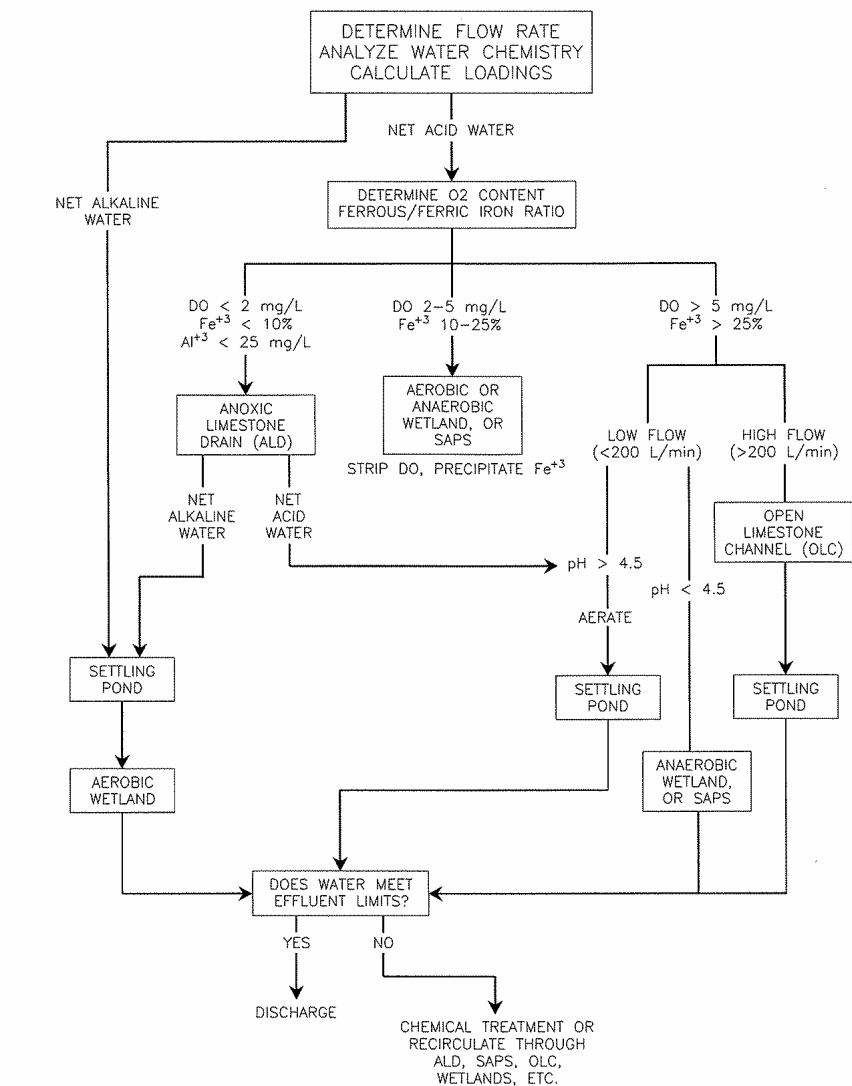
The available water quality data from the Richard Mine discharge at the Site is presented in Table 1. The comparison of the waters within Deckers Creek above and below the Site is presented in Table 2. The data within the tables was obtained from the NRCS and other sources including the WVDEP. It is unknown at this time if the data represents the culmination of the mine seal and mine opening flow or just the mine seal. No data was readily available for the water within the grass lined channel. In addition, as noted previously, the seep along Tibbs Run Road was dry and no historical data could be obtained.

AMD Treatment Technologies

AMD is attributed to the formation of highly acidic, iron and sulfate-rich drainage caused by the oxidation of sulfide minerals within the rocks and coal seams. The sulfide minerals oxidize in the presence of water and oxygen to form the AMD.¹ Treatment of AMD sources or drainages can be completed in two manners: active treatment technologies and passive treatment technologies.

Passive treatment encompasses a series of engineered treatment facilities that require very little to no maintenance once constructed and operational. Passive water treatment generally involves natural physical, biochemical, and geochemical actions and reactions, such as calcium carbonate dissolution, sulfate/iron reduction, bicarbonate alkalinity generation, metals oxidation and hydrolysis, and metals precipitation. The systems are commonly powered by existing water pressure created by differences in elevation between the discharge point and the treatment facilities.⁶ Figure 15 shows the relationship between water quality and choice of treatment system(s).

Once installed, passive treatment systems require little maintenance through the projected life of the system. They are a low-cost method of treating mine water. However, these systems have a finite life and may require rebuilding or rejuvenation over the life of treatment. The period of needed treatment can be considerable; some mines have continually yielded AMD for well over a century. Frequently, more than one type of passive treatment or an integrated system of passive treatment technologies is employed to treat mine drainage. These facilities, like conventional treatment facilities, are typically designed to raise the pH and remove metals (e.g., iron, manganese, and aluminum) of acid mine drainage.⁶



NOTE:
ADAPTED FROM HEDIN ET AL. 1994.

Figure 15

Open Limestone Channels (OLC)

Limestone has been shown to reduce acid loadings simply and inexpensively by introducing alkalinity to acid water in open channels or ditches lined with limestone. This method of treatment can be accomplished by using an open, free flowing channel lined with coarse limestone, and can often be constructed by lining an existing stream channel.² When implementing an open limestone channel, the length of the channel and channel gradient are design factors that can be varied for optimal performance. Open limestone channels are most effective in areas where rapidly flowing water is moving along a long sloping incline, and best performance is obtained in channels with slopes greater than 20 percent where flow velocities keep precipitates in suspension and clean precipitates from limestone surfaces.⁵ Open limestone channels are nearly

maintenance free when constructed to withstand washout during high flows. In an open limestone channel, the water will carry enough suspended ferric oxide to look polluted, so a settling basin can be used downstream of the channel to clarify the water prior to discharge.¹

Limestone Leach Bed (LLB)

A limestone leach bed (LLB) is another method of acid mine drainage abatement. This form of treatment involves passing surface water through a bed lined with limestone. Specifically, water slowly dissolves the limestone and effluent water generally contains an alkalinity concentration of 50 to 80 mg/L as CaCO_3 .⁸ Based on the topography of the area and the geometry of the discharge zone, the water can be from 1 to 3 meters deep, containing 0.3 to 1 meters of limestone immediately overlying the seep. The LLB is sized and designed to retain the water for 1 or 2 days for limestone dissolution, and to keep the seep and limestone under water.⁵

Vertical Flow Pond (Successive Alkalinity Producing System)

A vertical flow pond (VFP) can also be referred to as a Successive Alkalinity Producing System (SAPs) or a vertical flow wetland. In SAPs, acid water is ponded over organic compost which is underlain by limestone. Below the limestone is a series of drainage pipes that convey the water into an aerobic pond where metals are precipitated out of the water. Hydraulic head drives the ponded water through the anaerobic organic compost where oxygen is consumed and ferric iron is reduced to ferrous iron. After aeration and metal precipitation in a pond or wetland, water retaining net acidity can be passed through additional SAPs.⁴ When compared with horizontal flow anaerobic wetlands, vertical flow systems greatly increase the interaction of water with organic matter and limestone.²

The purpose of the organic layer is to consume oxygen and create a reducing environment, converting any ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}) and allowing it to pass through the limestone in dissolved form. However, due to limestone dissolution and increasing pH, aluminum (Al^{3+}) still reacts to form aluminum hydroxide solids in the treatment system. Over time, these solids can accumulate in the limestone and decrease the permeability of the treatment system, causing hydraulic failure.¹²

To combat this problem, the design of most VFPs includes the ability to flush large quantities of water through the system. The flushing systems that have been installed range from the inclusion of a valve on the existing underdrain system to a completely separate and multiple level flushing system equipped with several flush zones and valves.¹²

Aerobic/Anaerobic Wetland

Aerobic wetlands are generally used to collect water and provide residence time and aeration so metals in the water can precipitate.⁵ An aerobic wetland consists of typha and other wetland vegetation planted in shallow, relatively impermeable sediments comprised of soil, clay, or non-toxic mine spoil. Aerobic wetlands treat acid mine drainage by processes in the shallow surface layer.¹ These types of treatment areas are generally used to collect water and provide residence time and aeration so metals in the water can precipitate. Wetland plants encourage more uniform flow and thus more effective wetland area for water contact. Because of the extensive water surface and slow flow, aerobic wetlands promote metal oxidation and hydrolysis, causing precipitation and physical retention of iron, aluminum and manganese hydroxides.²

Anaerobic wetlands encourage water passage through organic rich substrates, which contribute significantly to treatment. The wetland substrate may contain a layer of limestone in the bottom of the wetland or may mix the limestone among the organic matter. Wetland plants are transplanted into the organic substrate.⁵ An anaerobic wetland consists of typha and other wetland vegetation planted in deep, permeable sediments such as soil, peat moss, spent mushroom compost, sawdust, straw/manure, hay bales, or a variety of other organic mixtures which are often underlain or mixed with limestone.¹ Wetland substrate may contain a layer of limestone in the bottom of the wetland or the limestone may be mixed among the organic matter. These systems are used when the water has net acidity, so alkalinity must be generated in the wetland and introduced to the net acid water in order to accomplish significant precipitation of dissolved metals. Several treatment mechanisms are enhanced in anaerobic wetlands as opposed to aerobic wetlands, including formation and precipitation of metal sulfides, metal exchange and complexation reactions, and microbially generated alkalinity due to reduction reactions.²

Anoxic Limestone Drain (ALD)

Anoxic Limestone Drains (ALD) are buried cells or trenches of limestone into which anoxic water is introduced where the limestone dissolves in the mine water and adds alkalinity.⁵ The sole function of an ALD is to convert net acidic mine water to net alkaline water by adding bicarbonate alkalinity to the water. Anoxic limestone drains improve the capability of wetlands to meet effluent limitations without chemical treatment. The removal of metals within an ALD is not intended and has the potential to significantly reduce the permeability of the drain resulting in premature failure, thus longevity of treatment is a concern for anoxic limestone drains, especially in terms of water flow through the limestone. Clogging of limestone pores with aluminum and iron hydroxides is common if appreciable amounts of dissolved iron (Fe^{3+}) and aluminum (Al^{3+}) are present, therefore, for acceptable design, iron (Fe^{3+}), dissolved oxygen, or aluminum (Al^{3+}) should not be present in the AMD. Elevation of the outflow from the ALD should be slightly above the top of the limestone so that the limestone remains water saturated at

all times to avoid access of air into the system. Effluent from the ALD usually flows into a wetland or pond, sized to oxidize and remove iron that will precipitate from the water, and for these areas, 15-hour contact times are desirable for optimal performance. Anoxic limestone drains may be a solution for treating specific types of acid mine drainage or for a finite period after which the system must be replenished or replaced. Anoxic limestone drains only raise pH and add alkalinity, so sufficient area must be provided beyond the drain for metal oxidation, hydrolysis, and precipitation to occur.²

Limestone Sand

This treatment method involves sand sized limestone particles being dumped into AMD streams at various locations within a watershed.⁵ The sand is picked up by stream flow and redistributed downstream furnishing neutralization of acid as the stream moves the limestone through the streambed. The limestone in the streambed reacts with the acid in the stream causing neutralization. Agitation and scouring of limestone in the streambed keep fresh surfaces available for reaction. The sand must be replenished 1 to 2 times per year depending on flood frequency. Limestone sand addition is most effective for streams with a low pH and relatively low dissolved metal concentrations.¹

Diversion Wells

A diversion well consists of a cylinder or vertical tank of metal or concrete filled with sand sized limestone that may be erected in or beside a stream or sunk into the ground beside the stream. Typically, a large pipe enters vertically down the center of the well and ends just above the bottom. Water is fed to the pipe from an upstream dam or deep mine portal then flows down the pipe, exits near the bottom of the well, then flows up through the limestone fluidizing the bed of limestone in the well.⁵ The flow rate of the water must be rapid enough to agitate the bed of limestone particles. Acid water dissolves the limestone for alkalinity generation and metal flocs produced hydrolysis and neutralization reactions are flushed through the system by water flow out the top of the well. Churning action of the fluidized limestone aids in limestone dissolution and helps remove iron oxide coatings so fresh limestone surfaces are always exposed, however limestone must be replenished as it is used, commonly done weekly.²

Steel Slag Leach Beds (SSLB)

Steel slags are byproducts formed during production of steel composed of hydrated amorphous silica and calcium compounds, especially calcium oxide, with smaller amounts of aluminum, magnesium, iron, titanium and manganese compounds and crystalline silica. These particles have high neutralization potentials and can generate exceptionally high levels of alkalinity over extended periods, and unlike limestone, slag particles do not armor with metals that precipitate out the treated water. Steel slag fines can leach extremely high levels of alkalinity over long periods of time, so they are excellent materials for leach

beds. Alkalinity production from a slag leach bed is determined by the amount of fresh water available to drive the leaching process. Slag fines leach beds will plug up if directly exposed to AMD or sediment because metals will precipitate within the slag mass and cause it to stop transmitting water. Thus, slag fines leach beds should only be used in conjunction with fresh, metal free transmitting water. Slag beds can be constructed so as to catch sediment-free runoff or to use direct rainfall, then the effluent from the leach beds can be allowed to infiltrate directly into a spoil or refuse pile to achieve in-situ AMD treatment or it can be combined with an AMD source to treat downstream of the spoil. Either application has the potential for very low maintenance AMD treatment.¹⁴

Bioremediation

Bioremediation of soil and water involves the use of microorganisms to convert contaminants to less harmful species in order to remediate contaminated sites. Microorganisms can aid or accelerate metal oxidation reactions and cause metal hydroxide precipitation. Other organisms can promote metal reduction and aid in formation and precipitation of metal sulfides. Reduction processes can raise pH, generate alkalinity, and remove metals from AMD solutions. Bioremediation of AMD has occurred in designed systems like anaerobic wetlands where oxidation and reduction reactions are augmented by special organic substrates and limestone.²

Source Control

At source control methods treat the acid-producing rock directly and stop or retard the production of acidity. Some techniques are partially successful and have demonstrated less than 100% control of acidity produced on site. This method may be suitable for an abandoned mine reclamation or a watershed restoration program. Removing a significant portion of the acid or metal load in a watershed may improve the health of a stream to a point of re-introducing some fish species or re-establish some designated uses of the stream. This method may be combined with another partial control scheme to achieve effluent limits and partial control methods are often less costly, so their use in combination with other techniques is often financially attractive.¹

Aeration

Removal of metals from mine drainage involves a host of chemical and biological processes including oxidation and hydrolysis reactions. The rate of reactions is dependent on many factors including pH, presence of bacterial catalysts, and the availability of oxygen. Oxygen availability becomes particularly important in treatment systems using aerobic processes such as settling ponds and wetlands. Oxygen is readily available in the atmosphere with the air we breathe containing approximately twenty percent oxygen. However, only about ten milligrams per liter (mg/L) oxygen can dissolve in water and encouraging the transfer of oxygen to mine water can be a challenge. Therefore, sufficient oxygen must be available

to effectively remove iron. Various techniques are available to aerate mine water that supplement the natural processes of oxygen transfer across the air-water interface and photosynthesis. All techniques require manipulation of available energy sources, which vary from site to site. The sources of energy may include water pressure, differential elevation head, wind power, electric power, or even solar power. The method selected should be based on mine water chemistry, treatment system objectives, and the availability of treatment area, hydraulic head, and electric power.

Therefore, limestone-based treatment systems, such as ALDs or VFPs, are inherently limited in the amount of alkalinity that can be added by each step (a treatment cell). Increases in alkalinity addition can be achieved cascading of treatment through the use of multiple VFP's (i.e. a SAPS) and/or adding a VFP to an ALD.

Active Treatment

Treatment, as normally applied to AMD, involves chemical neutralization of the acidity followed by precipitation of iron and other suspended solids. Treatment systems include:

1. equipment for feeding the neutralizing agent to the AMD
2. means for mixing the two streams (AMD and neutralizing agent)
3. procedures for ensuring iron oxidation
4. settling ponds for removing iron, manganese, and other co-precipitates

A number of factors dictate the level of sophistication of the treatment system that is necessary to ensure that effluent standards will be met. These factors include: the chemical characteristics of the AMD, the quantity to be treated, climate, terrain, sludge characteristics, and projected life of the plant. The chemicals usually used for AMD treatment include limestone, hydrated lime, soda ash, caustic soda, and ammonia. The following discussion highlights some of the characteristics of each of these neutralizing agents.

Limestone (calcium carbonate)

The calcium content level of the limestone should be as high as possible. Dolomitic limestones are less reactive and generally ineffective in treating AMD. Advantages of using limestone include low cost, ease of use, and formation of a dense, easily handled, sludge. Disadvantages include slow reaction time, loss in efficiency of the system because of coating of the limestone particles with iron precipitates, difficulty in treating AMD with a high ferrous-ferric ratio, and ineffectiveness in removing manganese. Limestone treatment is generally not effective for acidities exceeding 50 mg/l.

Hydrated Lime (calcium hydroxide)

Hydrated lime is normally the neutralizing agent of choice by the coal mining industry because it is easy and safe to use, effective, and relatively inexpensive. The major disadvantages are the voluminous sludge that is produced (when compared to limestone) and high initial costs that are incurred because of the size of the treatment plant.

Soda Ash (sodium carbonate)

Soda ash briquettes are especially effective for treating small AMD flows in remote areas. Major disadvantages are higher reagent cost (relative to limestone) and poor settling properties of the sludge.

Caustic Soda (sodium hydroxide)

Caustic soda is especially effective for treating low flows in remote locations and for treating AMD having high manganese content. Major disadvantages are its high cost, the dangers involved with handling the chemical, poor sludge properties, and freezing problems in cold weather.

Ammonia

Anhydrous ammonia is effective in treating AMD having a high in ferrous iron and/or manganese content. Ammonia costs less than caustic soda and has many of the same advantages. However, ammonia is difficult and dangerous to use and can affect biological conditions downstream. The possible off-site impacts are toxicity to fish and other aquatic life forms, eutrophication and nitrification. Fish species generally exhibit low tolerance to unionized ammonia and toxicity levels can be affected by pH, temperature, dissolved oxygen and other factors.

Other Possible Technologies

In addition to the passive and active treatment methods discussed above, other methods can be employed to mitigate the AMD discharge from the Richard Mine. Possibilities like injection of material into the mine and transporting the AMD to a different locale are among those to be discussed in the alternatives analysis phase of the Project.

Conclusion

The Richard Mine AMD discharge is an important issue and has been reviewed by many people and organizations. The amount of background data on the mine and its effects on local residents and streams has provided the necessary insight to the problems at the Site. Further field review and additional water quality data would provide a better understanding of the situation and ultimate solution to the problem.

Based upon the information provided and obtained, some conditions that may effect the Richard Mine discharge have been modified and would require additional analysis. One such condition is the former Tibbs Run Reservoir. According to the available information, a mine entry was located near the former reservoir location. As this may be a potential inflow point, additional study would be recommended.

Due to the lack of subsurface information on the Richard Mine, more detailed studies would need to be conducted, including but not limited to, mine pool elevation investigation and actual coal elevation and dip studies.

Using the available water quality data for the design of treatment structures could cause a conservative approach due to the fact that the data, for the most part, is older. More current data on a consistent schedule would prove to be beneficial.

The combination of this evaluation report and the bench scale testing (found under separate cover) provides the basis needed to conduct an alternative analysis for the potential reduction / elimination of the AMD discharge from the Richard Mine.

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